# PATENT SPECIFICATION

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COMPLETE SPECIFICATION

## Improved Air Spring

We, THE GENERAL TIRE & RUBBER COMPANY, of No. 1708 Englewood Avenue, Akron, County of Summit, State of Ohio, United States of America, a corporation organized under the laws of the State of Ohio, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to improved air springs or pneumatic suspension devices for use in automobile and other vehicle suspension systems.

While it has long been recognized that air springs possess certain inherent advantages over suspension devices, such as coil springs and leaf springs, air springs are not at present in general use in automobiles and other vehicles because of certain problems of design, cost and construction which have to be over-come.

According to the invention an air spring for cushioning and absorbing shocks and vibrations resulting from relative motion between a frame and undercarriage of a vehicle, comprises at least one piston member mounted on one of such members having relative motion, a bellows of rubberlike material sealed to the edge portion of the face of said piston member to define therewith an air-tight main air chamber, constraining means surrounding said bellows which is substantially coextensive in length with said bellows, and an auxiliary air chamber connected to said main air chamber by an orifice providing substantially unrestricted communication between said main air chamber and said auxiliary air chamber.

Preferably the piston member has sidewall portions of greater lateral extent than that of the face of said piston member to increase the effective area as said piston member approaches maximum deflection in compression.

Alternatively where a single piston is used, this may be of elongated form, said piston member extending inside of said constraining means so that its face reciprocates therein throughout substantially all of the normal operating cycle.

In order that the invention may be clearly understood and readily carried into effect reference is directed to the accompanying drawings, wherein:—

Figure 1 is a side elevation of an air spring of the present invention disposed between a vehicle frame and vehicle undercarriage;

Figure 2 is a side elevation in cross-section of the air spring of Figure 1, somewhat enlarged, the spring being in the middle or normal deflection position;

Figure 3 is a view similar to Figure 2 showing the spring in the position of full jounce in solid line, and in the position of full rebound in dotted lines;

Figure 4 is a side elevation in cross-section similar to Figure 2 showing a modified form of air spring;

Figure 5 is a side elevation in cross-section similar to Figure 3 showing a second modified form of air spring;

Figure 6 is an enlarged side elevation in cross-section of a portion of the bellows and piston of the air spring of Fig. 5;

Fig. 7 is a side elevation in cross-section showing a third modified form of air spring;

Fig. 8 is a side elevation in cross-section of the modification of Fig. 7 in full jounce;

Fig. 9 is a side elevation in cross-section of a fourth modified form of air spring similar to the modification of Fig. 7;

Fig. 10 is a plan view, partly in cross-section, of a fifth modified form of air spring;

Fig. 11 is a front elevation, partly in cross-section, of the modification of Fig. 10;

Fig. 12 is a side elevation of the modification of Fig. 10;

Fig. 13 is a detail in cross-section of the modification of Fig. 10;

Fig. 14 is a graph of effective area against spring height for the air spring of Figs. 1 through 3 in dash line (curve B) and for the air spring of Figs. 7 and 8 (curve A) in solid line; and

Fig. 15 is a graph of load against spring

height for the air spring of Figs. 1 through 3 (curve C) in dash line, for the air spring of Figs. 7 and 8 (curve D) in solid line, and for the air spring of Fig. 9 (curve E) in dot-dash line.

The present invention comprises an air spring having opposing piston members, rubber bellows sealed to the edges of the piston members so as to form therewith a main air chamber, and a floating band attached to the bellows and surrounding and constraining it. This air spring is readily incorporated in automobile and other vehicle suspension units and allows for appreciable misalignment between the top and bottom piston members. Furthermore, the profiles of the piston members are tapered or otherwise shaped to provide the desired spring characteristics.

Referring to Fig. 1, an air spring unit 1 is shown mounted between a vehicle frame or chassis 2 and vehicle undercarriage 3. Inasmuch as the particular suspension system in which the air spring unit is employed is not material to the present invention, it has not been shown. The portion shown is similar to a front end suspension of an automobile, the wheel being mounted to the left of Fig. 1. The undercarriage portion 3 pivots about a point 16 to the right of Fig. 1 and moves over an arcuate path toward and away from the chassis portion 2.

In accordance with the present invention, a frame or top piston member 4 is mounted on frame portion 2 and an undercarriage or bottom piston member 5 is mounted on undercarriage portion 3. Piston members 4 and 5 are directed at and facing one another as shown in Fig. 1 and are in substantial alignment in full jounce. All or part of the piston member may be separately fabricated and welded or otherwise fastened to the member upon which it is mounted as is piston 4 or it may be formed integrally with the member upon which it is mounted as is piston 5. Mounted intermediate the piston members and sealed therewith so as to form an air-tight main chamber 25 are cylindrical rubber bellows 6. Surrounding the bellows 6 is a floating, cylindrical constraining band 7 which is substantially coextensive in height with the bellows along the longitudinal axis L—L of the constraining band, the longitudinal axis L—L being the axis through the center of the constraining band.

The faces 24 and 26 of the piston members 4 and 5 project approximately one-fourth or less of the way into the cylindrical band or cam 7 in the normal load or design height position of the unit as is shown in Fig. 2. The diameters of the faces of the piston members are also somewhat smaller than the inner diameter of the cylindrical band so that there is appreciable clearance between the sidewalls of the bellows and the edge of the piston face. The piston members thus reciprocate within the top and bottom edges of the cylindrical band throughout most of the operating cycle, the only exception being toward and in the full rebound position. It should be noted that the piston members must have both a face and substantial sidewall portions, the purpose of the sidewalls being to control the bellows formation adjacent the piston face as it moves in the band.

The bellows or bladder is preferably made of tyre carcass rubber stock but any rubberlike material having sufficient strength, resistance to deterioration in use, and air-tightness is satisfactory. For example, the more rubberlike polyurethanes are suitable materials for the bellows. For use in automobile suspension systems, the walls of bellows made from tyre carcass stock should preferably be from 1/16" to 3/16" thick.

Referring to Fig. 2, the bellows 6 embraces and is assembled with the piston members so as to form annular ring portions 8 and 9 about the edge portions of the top and bottom piston members terminating with heads 10 and 11 at the edges of the piston members. As assembled on the air spring unit, the bellows is generally circular in a cross-section taken at right angles to the longitudinal axis L—L and is of a cylindrical shape with rounded annular edge portions and with centrally dished-in top and bottom portions in the cross-section taken through the longitudinal axis L—L. The dished-in top and bottom portions are adapted to interfit with and accommodate the piston members 4 and 5. Describing the shape of the bellows another way, it is similar to a cylinder with annular beaded portions around the top and bottom which define central dished portions adapted to receive the piston members.

As molded and prior to assembly, the bellows is cylindrical in shape with convexly rounded top and bottom portions. When assembled, the top and bottom portions are pushed in and reversed to form the central dished-in end portions and annular beaded portions shown. Other generally cylindrical shapes with beaded ends defining a central, circular piston receiving opening which vary from the molded toward the assembled shapes described above may be employed. The shape should be such, however, that the walls of the bellows are not lapped away or back from the cylindrical band in full jounce to an appreciable extent and folds are not formed in the annular bellows portions 8 and 9 which tend to crack or otherwise destroy them in use.

The beaded end portions comprise a bead 10 which fits in a bead seat 12 in the piston member 4 and a bead 11 which fits in a bead seat 13 in the piston member 5, both heads making an air-tight seal with the piston member similar to the seal between the beads of tubeless tyres and the rim. The beads 10 and 11 are reinforced with bead wires 14 and 15 which are solid wires butt welded at the joints.

Bead wires similar to those used in pneumatic tyres may also be employed.

The cylindrical constraining band 7 surrounding the bellows is floating and, except for the bellows, is unattached to other elements of the unit. It reciprocates with the movement of the undercarriage piston member as is shown in Fig. 3 and provides the means for compensating for misalignment between the top and bottom pistons while limiting the diameter of the unit to maintain the characteristics of an air spring. The band 7 may be welded from light gauge sheet metal, forged, or otherwise formed as described. It is held in position on the bellows by a central groove or corrugation 19 formed in the band which interfits with a corresponding central ridge or bead 20 formed on the outer periphery of the bellows. One or more corrugations and corresponding ridges or other means may be provided as necessary to hold the band in position on the periphery of the bellows.

The band must have appreciable length so as to accommodate the piston members as they reciprocate within it. Likewise, the faces of the piston members should extend into the band so as to operate and reciprocate within it throughout most of the operating cycle of the unit. As the unit approaches full rebound, however, the faces of the piston members may be outside the cylindrical band. This is illustrated in the view in Fig. 3 in dotted lines in which the face 26 of the piston 5 is substantially outside of the band 7. Full jounce is maximum deflection in compression and full rebound is maximum deflection in expansion.

The constraining band constrains substantially the entire outer periphery of the bellows except for the top and bottom annular beaded portions 8 and 9. When the suspension assembly is in the normal, loaded position, the edge portions 21 and 22 of the band should preferably extend longitudinally beyond the face of the piston members. This is illustrated in Fig. 2 in which line F—F constitutes a line in the plane of the face of the piston member 4. Edge portions 21 of the band extend longitudinally, that is along axis L—L, beyond this line. The edge portions 21 and 22 are flared outwardly so that they do not bite into the sides of the bellows.

An orifice 23 is formed in the face 24 of the piston 4 and leads or connects from a main air chamber 25 defined by the inner walls of the bellows, the face 24 of the piston 4 and the face 26 of the piston 5 into an auxiliary air chamber 27 defined by the inner walls of the piston 4, a cylinder member 28 and a closing portion, not shown. The size of the main chamber 25 defined by the bellows and of the auxiliary chamber 27 may be varied to give the desired spring rate and frequency. Generally the auxiliary air chamber should be three or four or more times larger than the main air chamber. It may also be smaller, however, as in Figs. 7—9 hereinafter described. The air pressure in the air chamber is kept at 20 up to 100 p.s.i. or more depending upon the load and size of the air spring in relation to the load.

The sidewall portions 29 and 30 of the pistons 4 and 5 diverge outwardly from the face of the pistons toward the base of the pistons so that the radius of the base of the piston is greater than the radius of the face of the piston, In other words, the pistons are preferably frusto-conical, instead of cylindrical with the apex portions directed at or facing one another. This is shown in Fig. 2. In this figure, line A—A is a line at right angles to the face 26 of piston 5 so as to illustrate the taper of the piston sidewall or profile. The angle of taper of the profile may be from 2° up to 15° or 20°.

As the air spring moves from its normal loaded position as shown in Fig. 2 to a position of full deflection in compression as shown in solid line in Fig. 3, the inside edge portions 31 and 32 of the annular beaded portions of the bellows lap or come to rest against the sidewalls 29 and 30 of the pistons so as to increase the diameter of the effective area of the air spring. This, in turn, stiffens the spring characteristic and increases the spring rate and frequency. By so varying the piston profiles, the spring rate of the air spring may be controlled and readily adapted for use in automobiles.

Fig. 4 shows an air spring similar to that of Figs. 1—3 except that the sidewalls or profiles 38 and 39 of the frame and chassis pistons 40 and 41 are straight or at right angles to the piston faces. In other words, the pistons are cylindrical in shape. In order to provide for an increased effective area, the thickness of the walls of the hook portions 42 and 43 of the bellows 44, which portions fold or lay up against the piston sidewalls as the piston faces move together, is increased from the beads 45 and 46 outward toward the outer edges 47 and 48. The effective area of the air spring is thus increased as the spring nears maximum deflection in compression so that the spring functions similarly to the spring of Figs. 1—3.

Figs. 5 and 6 show still another modification of the present invention in which the diameters of the frame and undercarriage pistons increase from the face to the base in a step fashion instead of being gradually tapered as in Figs. 1 through 3. This is best shown in Fig. 6 in which the sidewall 53 of the top piston 54 has a straight portion 55 running parallel to the longitudinal axis from the rim or edge of the piston 56 to an intermediate seat portion 57 in the piston sidewall. The seat portion 57 of the piston rapidly increases the piston diameter and, correspondingly, the effective area. A second straight portion 58 is formed in the piston from the seat portion to the flat

base portion 59 welded to the frame. If desired, the piston sidewalls may be increased and varied in other ways to increase the effective area from the face of the piston to the base. For instance, the sidewalls may be provided with two or more step portions, the portions connecting the step portions may be tapered, and other modifications may be employed to vary the effective area. Likewise, one of the pistons may be cylindrical in shape with sidewalls parallel to the longitudinal axis and the other piston may be frusto-conical or otherwise shaped so as to increase the effective area as the position of maximum compression in deflection is reached.

As used herein, the effective aea is the area acting at right angles to the longitudinal axis of the band as the pistons move toward and away from one another. Assuming that the face of the piston is at right angles to the longitudinal axis of the band (which is not always the case), the effective area comprises the area of the face of the piston plus the plan or projected area of the surrounding concentric bellows portions acting with the piston as such and not as a constraining band. This is shown in Fig. 6. D represents the diameter of the effective area at the normal loaded position. $D^1$ represents the diameter of the effective area at maximum deflection in compression. As can be seen, the diameter of the effective area increases as the piston members move from normal load position out to the maximum deflection position so as to increase the spring rate.

In connection with the action of the piston sidewalls in controlling the effective area, it should be noted that the control is positive and accurate because the pliable bellows laps up against a rigid piston sidewall. The bellows is not free to change shape in an uncontrolled manner. Also, the variation in the effective area is of a minor order and the effective area is substantially constant when compared with other air spring units.

Referring back to Fig. 5, the beads 61 and 62 of the bellows 63 are sealed to the faces of the piston members by circular clamping members 64 and 65. The faces 51 and 52 of the piston members are dished so as to receive the beads of the bellows and conform to the clamping members. The clamping members are bolted to the faces of the piston members as shown, the flange portions 71 and 72 of the clamping members holding the beads in a sealing position against the faces of the piston members. An orifice 74 defined in the face of the top or frame piston member provides connecting means between the main air chamber 75 and auxiliary air chamber 76. An inner ring 36 holds the bellows 63 in the groove 37 formed in the band 73 and thereby positively holds the band on the bellows.

The purpose of the clamps is to hold the beads on the seats when the spring is extended in full jounce or when the suspension is extended without air pressure, for example, when the vehicle is jacked up to change a tyre. The purpose of the supporting ring 36 is to keep the band in position on the bellows when the unit is designed so that the bellows is placed in elongation in full jounce and thereby takes up some of the rebound.

Figs. 7 and 8 illustrate still another air spring of the present invention which is characterized by having a single elongated piston member, such as a piston 77, having a longitudinal height of the same order as the band and being mounted on the undercarriage or the frame. This arrangement permits use of a small volume auxiliary air chamber and gives a lower frequency than that given by the modifications of Figs. 1—6. At the same time, there is an inherent variation in the effective area which gives spring characteristic curves corresponding to the curves desired by the automobile manufacturers.

Referring to Fig. 7, an elongated piston 77 is mounted on the undercarriage. The piston may also be mounted on the frame as is shown in Fig. 9. The height of the piston should be such that its face reciprocates within the band throughout the major portion of the operating cycle of the unit from full jounce to full rebound. The piston has substantially the same height as the band but the normal centerline of the piston is closer to the member upon which it is mounted so that the piston and band are offset as shown. If they were not offset, the band would strike the member upon which the piston is mounted in the full jounce position.

It should be noted that an important feature of the air springs of Figs. 7, 8 and 9 is the fact that they permit considerable annular misalignment between the chassis and undercarriage.

Surrounding the bellows 78 and substantially coextensive therewith is a floating constraining band 84. As noted, the band is positioned on the bellows so that it does not interfere with the chassis or undercarriage in full jounce or in full rebound and has substantially the same height as the piston. A central groove 85 in the band 84 interfits with a bead 86 in the bellows and thereby holds the band on the bellows. A bead 79 of the bellows 78 rests and seals with an annular groove 81 formed in the chassis.

In a similar fashion a bead 80 rests and seals in a groove 82 in the piston 77. A cylindrical member 88 welded to the chassis defines an orifice 89 in the chassis which leads from the main air chamber 90 into an auxiliary air chamber 91. The main air chamber 90 is defined by the bellows 78 and the face 83 of the piston 77. The auxiliary air chamber 91 is defined by the cylindrical container 92. An advantage of the subject modification is the fact that the volume of the auxiliary air

chamber may be about the same or even less than the volume of the main air chamber. The other modifications of the present invention require an auxiliary air chamber which is generally three or four times greater than the volume of the main air chamber.

In the normal load position, the piston 77 preferably extends about to the middle portion of the band 84. It also should have enough height so that the bottom annular portion of the bellows does not interfere with the chassis in any position.

The length of the band and its placement relative to the piston 77 must be carefully worked out so that the relationship of the edges of the band to the loop formed in the bellows at the side of the piston is correct. The loop should contact the flanged-out corner portion 136 as the piston face 83 approaches the chassis so as to prevent contact between the two. At the same time, the clearance must be minimal so that the overall height of the unit is as low as it can be made. Likewise, the rate of change of effective area must be carefully worked out so that the optimum performance curve is obtained. The rate of change should preferably be such that there is a rapid increase in net effective area as normal load height is approached from full rebound, a decreasing effective area over the middle load positions, and large increase at full jounce. When the air spring of Figs. 7—9 is properly designed as described, frequencies in the order of 50—70 and as low as 40 cycles per minute can be obtained combined with high capacity and suitable stiffness as full jounce is approached.

Figure 9 is a modification similar to that of Figs. 7 and 8 in which the elongated piston 93 is mounted on the frame instead of the undercarriage and has inwardly curved sidewalls 94 instead of straight sidewalls. In addition, the bellows 120 is provided with a central, cylindrical, band of reinforcing substantially inextensible fabric 121 bounded by top and bottom beads 122 and 123 to form a central inextensible portion similar to that formed by the band 84 of Fig. 8. The fabric can be any conventional tyre fabric such as rayon or nylon and is incorporated in the bellows similar to a tyre carcass in a tyre casing. The fabric is preferably at least twice as strong in the direction of the warp threads as in the direction of the weft threads, the warp threads running substantially parallel to the face 125 of the piston 93. Beads 122 and 123 are preferably but not necessarily incorporated in the bellows in the vicinity of the edge of the fabric band to further reinforce and strengthen the unit and provide a constant diameter.

An orifice 124 is formed in the face 125 of the piston 93. The orifice opens into an auxiliary air chamber 126 defined by the inner walls of the piston and rounded closing portion 127 at the foot of the piston. Air is supplied to the unit through a valve 128.

The bellows 120 is also provided with beads 129 and 130 at the edges thereof which seal with the edges of the face 125 of piston 93 and the bead seats 131 formed in the undercarriage. The bead 130 is sealingly clamped to the undercarriage by a clamping member 133, a bolt 134 and a nut 135 as shown. The portion of the undercarriage enclosed by the bead 130, the inner walls of bellows 120, and the face and sidewalls of the piston 93 define the main air chamber 132.

A unit provided with an integrally reinforced bellows but without a separate can or circumferential supporting member as shown in Fig. 9 is not the full equivalent of the unreinforced bellows and can arrangement of the other modifications because the loop of the bellows cannot withdraw into the can. This may be overcome by providing a vertical separation between the inner and outer portions of the bellows adjacent the edges, but there is always a tendency to enlarge the separation at its central terminals as the unit works. At the same time, the unit of Fig. 9 is suitable in many installations in place of the other modifications described herein. Because the loop of the bellows cannot withdraw into the can, this unit has a straighter curve and variations at the jounce and rebound ends have to be achieved by using shaped pistons as shown.

Figs. 10—13 illustrate another modification of the present invention which is characterized by having an elongated, rectangular-with-rounded-ends cross-sectional shape as shown in Fig. 10. The cross-sectional shape of all other modifications is circular and that is the preferred shape.

In other respects, the air spring of Figs. 10—13 is similar to that of Figs. 1—3. It has a floating constraining band 96 surrounding a rubber bellows 97. A piston 108 is mounted on the chassis and a piston 109 is mounted on the undercarriage. A clamp 102 clamps and hold the bead 98 against the face of the piston 108 and clamp 103 clamps and holds the bead 99 against the face of the piston 109.

The walls of the band are prevented from expanding outwardly by bracing members 117 and 118. As shown in Fig. 12, the bracing member 118 comprises a long bolt 111, a flanged pipe 112 surrounding the bolt and substantially coextensive therewith, a washer 114, and a nut 110. The pipe is provided with a flange 113 which has concentric ridges 115 and grooves 116 so as to make an airtight seal with the bellows 97. This prevents leakage of air past the hole 119 made in the bellows to accommodate bolt 111.

The side view of the instant modification of the present invention is the same as the circular units and illustrates their similarity.

Figs. 14 and 15 are graphs illustrating the characteristics of the air springs of the present invention. Fig. 14 shows the apparent effec-

tive area taken under static conditions plotted against spring height for the air springs of Figs. 1—3 and of Figs. 8 and 9. Curve A represents the air spring of Figs. 7 and 8 as it goes from full rebound to full jounce and back again. Curve B represents the air spring of Figs. 1—3 as it goes from full rebound to full jounce and back again. The solid vertical line represents the normal height for curve A. Full rebound is at the left-hand side of the graph. The apparent effective area is the load divided by the air pressure in the unit.

It is apparent from curve A that the effective area of the piston of Figs. 7 and 8 is low at full rebound, rises sharply, and then drops rapidly through normal position before the rise at jounce. This gives a soft, high capacity and small volume air spring. Curve B shows the effective area of the air spring of Figs. 1—3. It is low at full rebound, increases rapidly, levels off over the middle range, and then increases again because of the increasing diameter of the sidewalls of the pistons 4 and 5. For a given total volume, the spring of Figs. 1—3 is stiffer than that of Figs. 7 and 8.

Fig. 15 shows load plotted against spring height. Curve C is for the air spring of Figs. 1—3, curve D is for the air spring of Figs. 7 and 8, and curve E is for the air spring of Fig. 9. The characteristics of each air spring are apparent from the curves. The air spring of Figs. 1—3 (curve C) has the flattest overall curve because it has the largest volume and two pistons. It is relatively soft at rebound and soft at jounce. If the pistons of the air springs of Figs. 1—3 had straight profiles, curve C would be flatter in the right-hand portion, indicating that the air spring would not be as stiff at full jounce. The air spring of Figs. 7 and 8 (curve D) is stiffer than that of Figs. 1—3 at rebound and at jounce. The air spring of Fig. 9 (curve E) is stiffest at rebound and at jounce, the effect of the hourglass piston shape being quite apparent. Although the springs have approximately the same effective area over the middle range, the volume of the air spring of Figs. 1—3 is over five times that of the air spring of Fig. 9. The volume of the air spring of Figs. 7 and 8 is between that of the other two, being slightly less than twice that of the air spring of Fig. 9. The design or normal height is indicated by the vertical line N and is the same for all curves. Rebound is at the left-hand side of the design height and jounce is at the right-hand side.

In regard to the characteristics of air springs it should be noted that the automobile manufacturers are not in full agreement as to the ideal frequency or characteristics for such units and that each unit has to be tailored for each manufacturer. One of the principal advantages of the present invention is the fact that the characteristics of the unit can be readily altered and adopted to the requirements of each manufacturer by changing the profile of the piston or pistons.

WHAT WE CLAIM IS:—

1. An air spring for cushioning and absorbing shocks and vibrations resulting from relative motion between a frame and undercarriage of a vehicle, said air spring comprising: at least one piston member mounted on one of such members having relative motion, a bellows of rubberlike material sealed to the edge portion of the face of said piston member to define therewith an air-tight main air chamber, constraining means surrounding said bellows which is substantially coextensive in length with said bellows, and an auxiliary air chamber connected to said main air chamber by an orifice providing substantially unrestricted communication between said main air chamber and said auxiliary air chamber, said piston member having side-wall portions of greater lateral extent than that of the face of said piston member to increase the effective area as said piston member approaches maximum deflection in compression.

2. An air spring as claimed in claim 1 wherein a first piston member is mounted on the vehicle frame, a second piston member is mounted on the vehicle undercarriage and directed toward said first piston member, said bellows being sealed to the edge portion of the faces of both piston members to define therewith the air-tight main air chamber, and wherein said constraining means comprises a floating band surrounding and attached to the periphery of said bellows and substantially longitudinally coextensive therewith.

3. An air spring as claimed in claim 2 wherein said bellows as assembled has annular edge portions and central dishout portions in the top and bottom faces thereof surrounding and interfitting with said piston members.

4. An air spring as claimed in any of the preceding claims wherein the sidewalls of at least one of said piston members has at least one step portion which, as said piston members approach maximum deflection in compression, provides an effective area greater than the effective area provided by the face of the piston member in the normal load position.

5. An air spring as claimed in claim 4 wherein at least one end of said bellows has wall portions of outwardly increasing thickness which, as the piston members approach maximum deflection in compression, provide an effective area greater than the effective area provided by the face of the surrounded piston member in normal load position.

6. An air spring as claimed in claim 1 wherein said piston member extends an appreciable distance inside of said band so that the face of said piston reciprocates within said band throughout substantially all of the operating cycle.

7. An air spring as claimed in claim 2 wherein said piston members extend an appreciable distance inside of said band so that their

faces reciprocate therein throughout substantially all of the operating cycle.

8. An air spring as claimed in claim 1 in which said piston is mounted on the vehicle frame and is elongated, and in which said bellows is sealed not only to said piston but to the undercarriage of the vehicle substantially opposite the face of said piston.

9. An air spring as claimed in claim 2 wherein at least one of said piston members has side-wall portions which have greater lateral dimensions than the corresponding lateral dimensions of the face of said piston member to increase the effective area as the pistons approach deflection in compression.

10. An air spring for cushioning and absorbing shocks and vibrations resulting from relative motion between a frame and undercarriage of a vehicle which comprises an elongated piston member mounted either on said undercarriage or said frame, bellows of rubber-like material sealed to the edge portions of the face of said piston member and to the undercarriage or frame opposite the face of the said piston to define therewith a main air chamber, constraining means surrounding said bellows which is substantially coextensive in length with said bellows, an auxiliary air chamber and an orifice providing substantially unrestricted communication between said main air chamber and said auxiliary air chamber, said piston member extending inside of said constraining means so that its face reciprocates therein throughout substantially all of the normal operating cycle.

11. The air spring of claim 10 in which the constraining means comprises a floating cylindrical band with relieved edge portions which is positioned on the periphery of the bellows.

12. The air spring of claim 10 in which the side wall portions of the piston are inwardly relieved.

13. The air spring of claim 10 in which the auxiliary air chamber is defined by the inside of the piston member.

14. The air spring of claim 10 in which the piston member is mounted on the undercarriage.

15. An air spring substantially as described and shown in the accompanying drawings.

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818,604 COMPLETE SPECIFICATION
5 SHEETS *This drawing is a reproduction of the Original on a reduced scale.*
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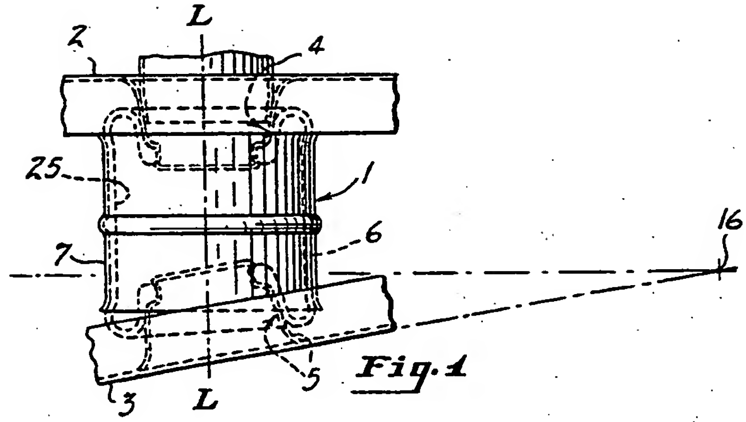


Fig. 1

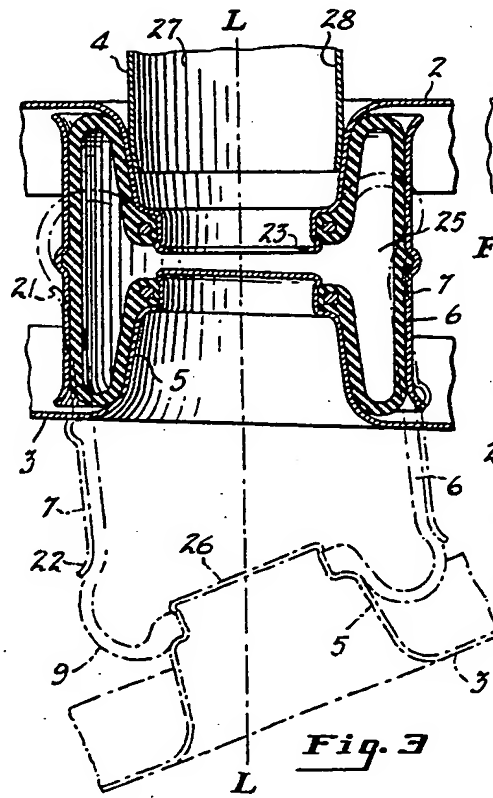


Fig. 3

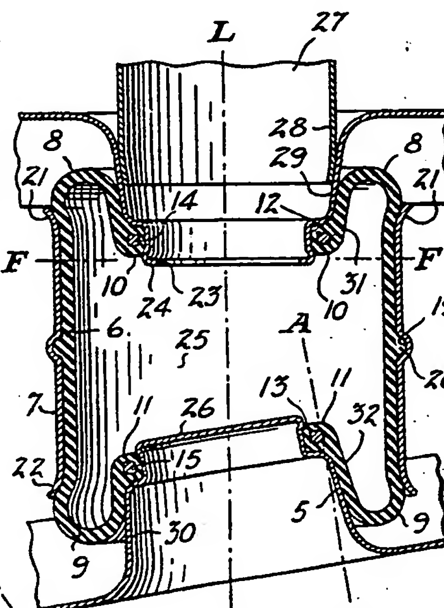


Fig. 2

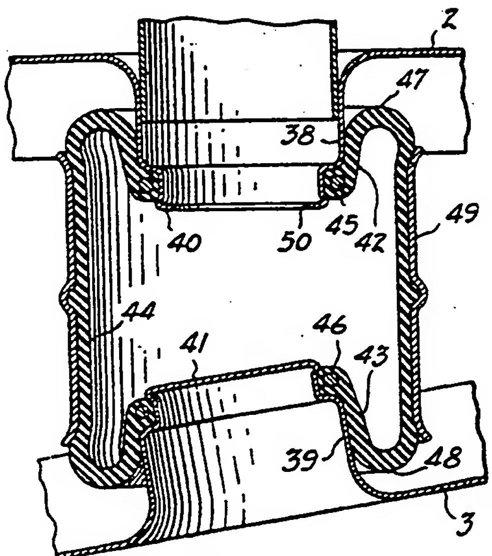


Fig. 4

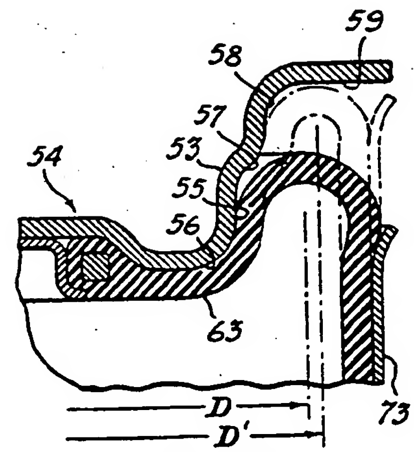


Fig. 6

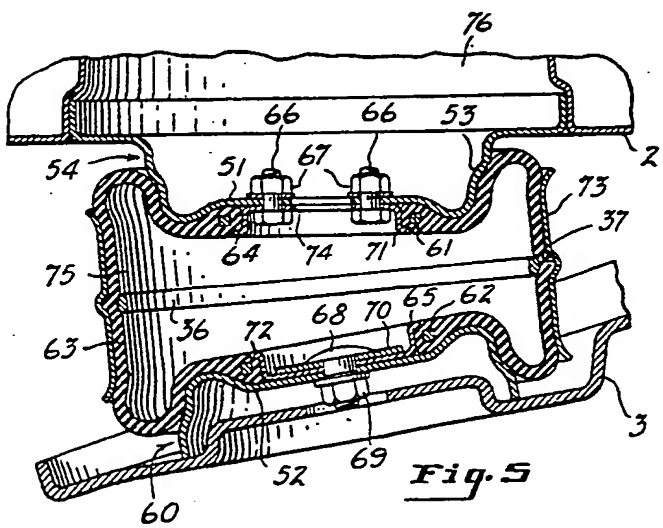


Fig. 5

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*This drawing is a reproduction of the Original on a reduced scale.*
SHEETS 2 & 3

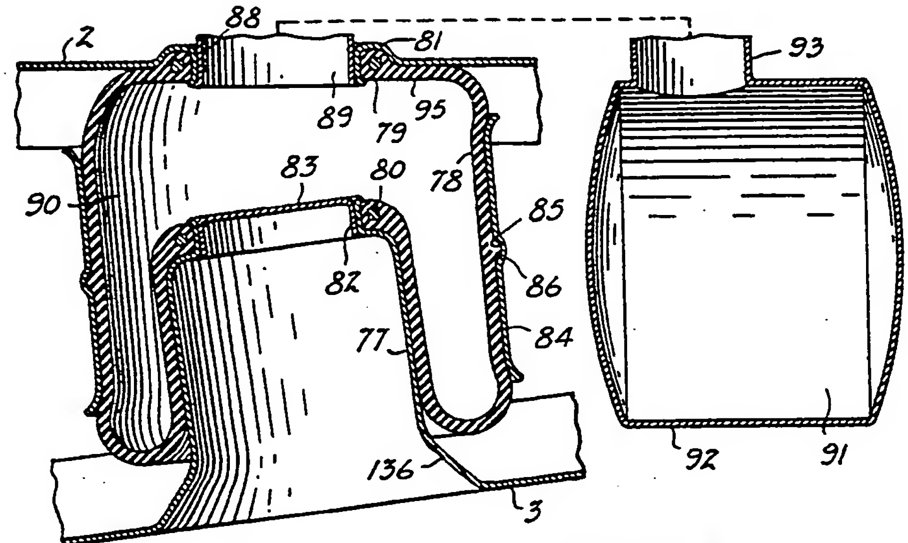


Fig. 7

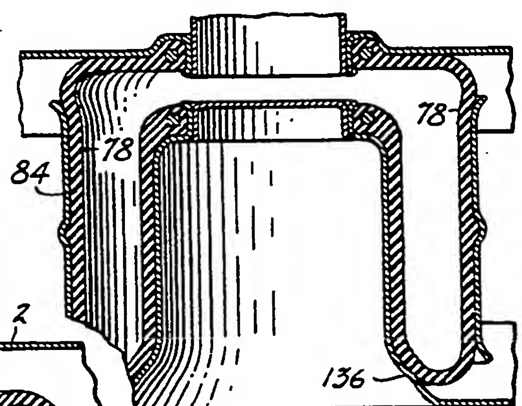


Fig. 8

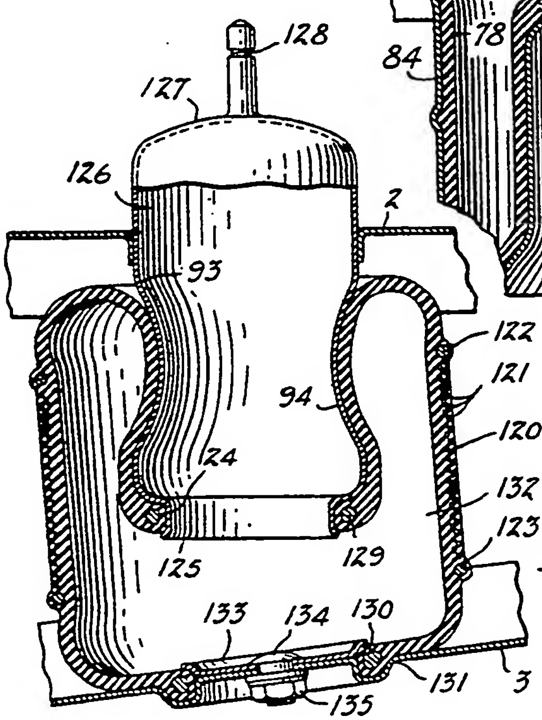


Fig. 9

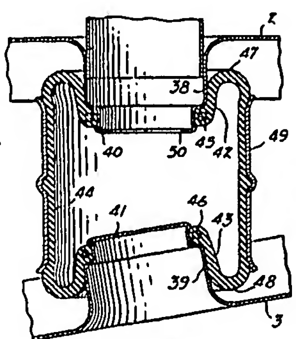


Fig. 4

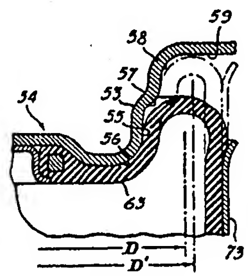


Fig. 6

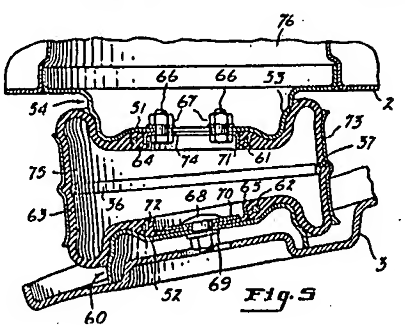


Fig. 5

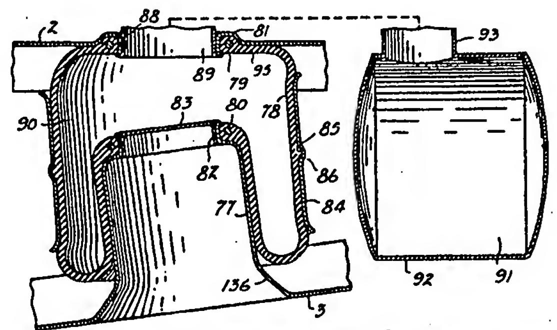


Fig. 7

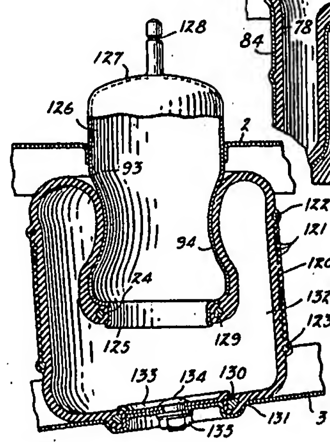


Fig. 9

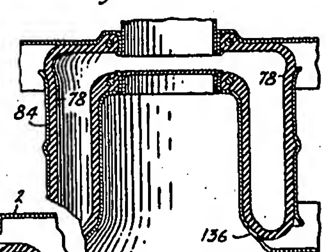


Fig. 8

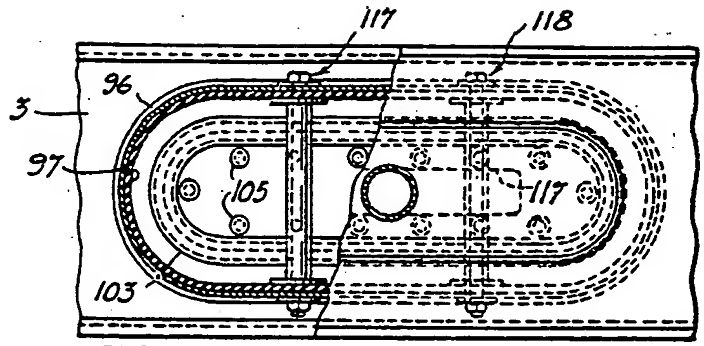


Fig. 10

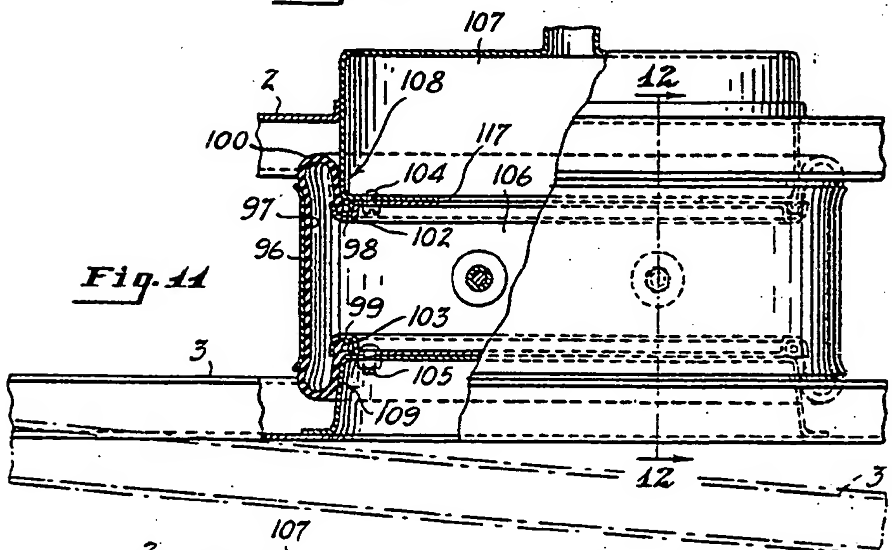


Fig. 11

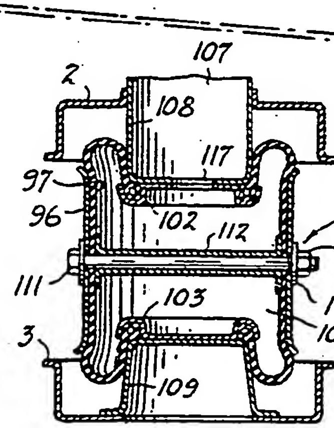


Fig. 12

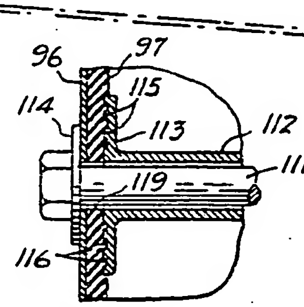


Fig. 13

818,604 COMPLETE SPECIFICATION
5 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEETS 4 & 5

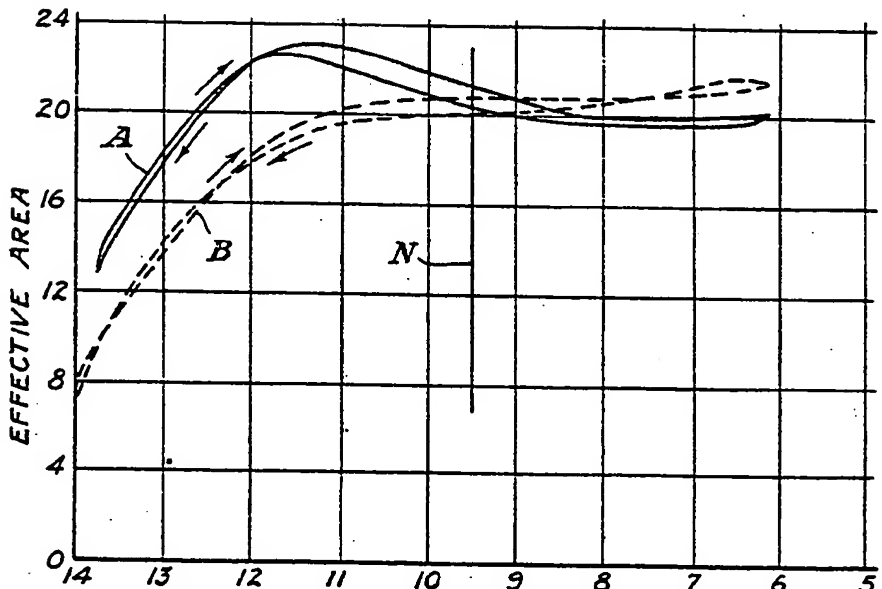


Fig. 14

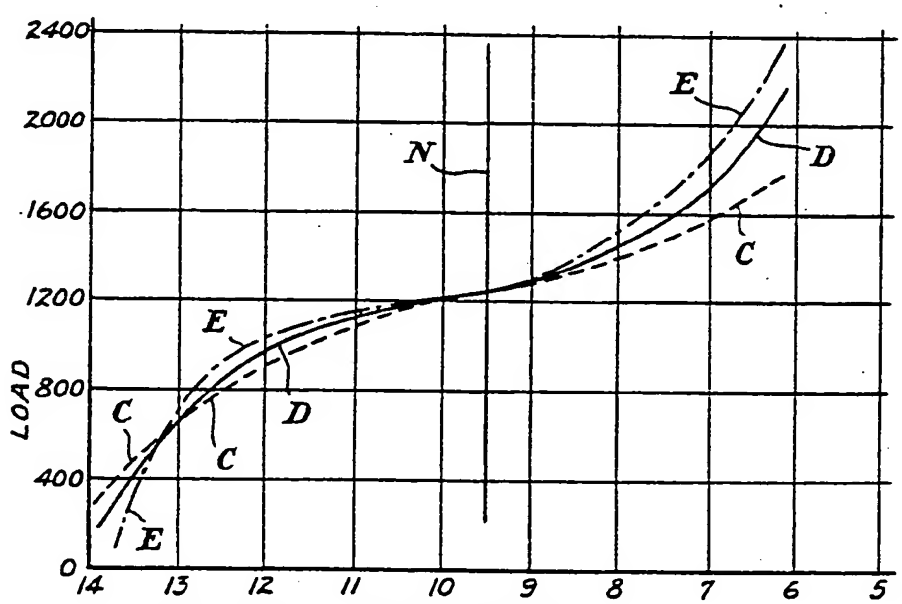


Fig. 15

818,604 COMPLETE SPECIFICATION
5 SHEETS
This drawing is a reproduction of the Original on a reduced scale.
SHEETS 4 & 5

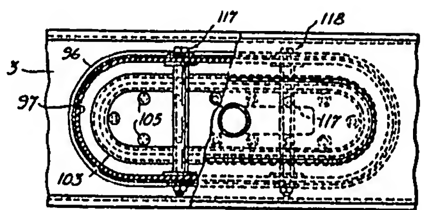


Fig. 10

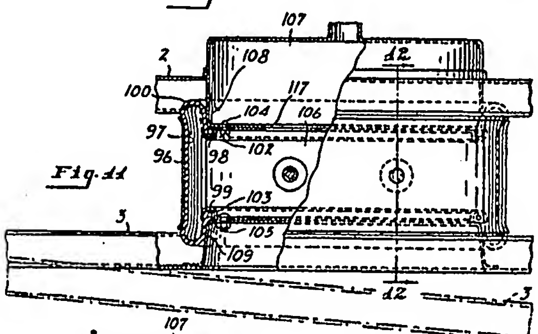


Fig. 11

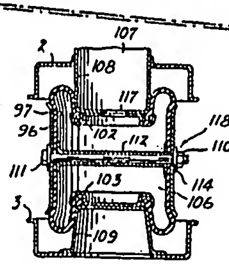


Fig. 12

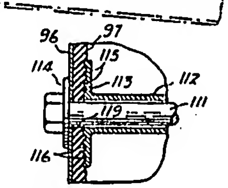


Fig. 13

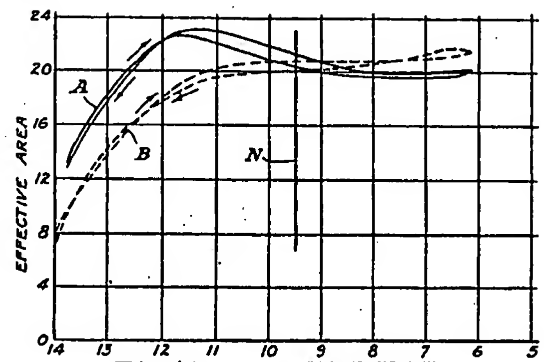


Fig. 14

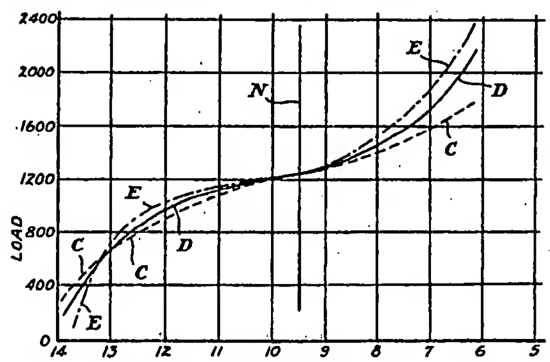


Fig. 15